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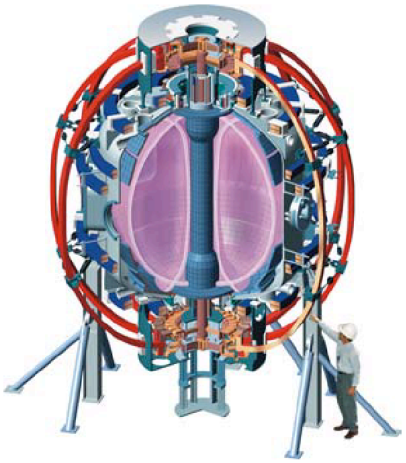
NSTX Lithium Plans and Requested R&D Support

H.W.Kugel



Plasma Facing Components Meeting
November 17-20, 2003
Oakbrook, IL

PPPL PRINCETON PLASMA PHYSICS LABORATORY

Outline

- NSTX Lithium Plan FY04- FY08
- The Path to NSTX Lithium Operations
- Requested near term technology support
- Requested near term support for the design & procedure review process.
- Summary and conclusions

NSTX Lithium Experiments Will Focus on Particle Control (FY'04) & Power Handling (FY'08)

- ***Particle Control Plan***

TFTR demonstrated the benefit of a partial lithium coating on carbon PFCs
- Strong edge pumping (reduction of recycling)
- Improvement in energy confinement (x2)

- **Lithium Pellet Injection (FY'04)**
  - **Use large capacity and multiple pellet capability**
- **Lithium Evaporator (FY'05)**
  - **CDX-U will test prototype modular evaporators**
  - **Use several evaporators to cover NSTX divertor regions**
  - **Benefit from CDX-U/LTX research to optimize substrate**
    - **possible change from carbon PFCs in FY'07**

- ***Particle Control and Power Handling Plan***
  - **Liquid Lithium Surface Module (FY'08)**
    - **Potential for both power and particle handling**

NSTX Experimental Plans in FY04 for Low-Z Pellet Injection

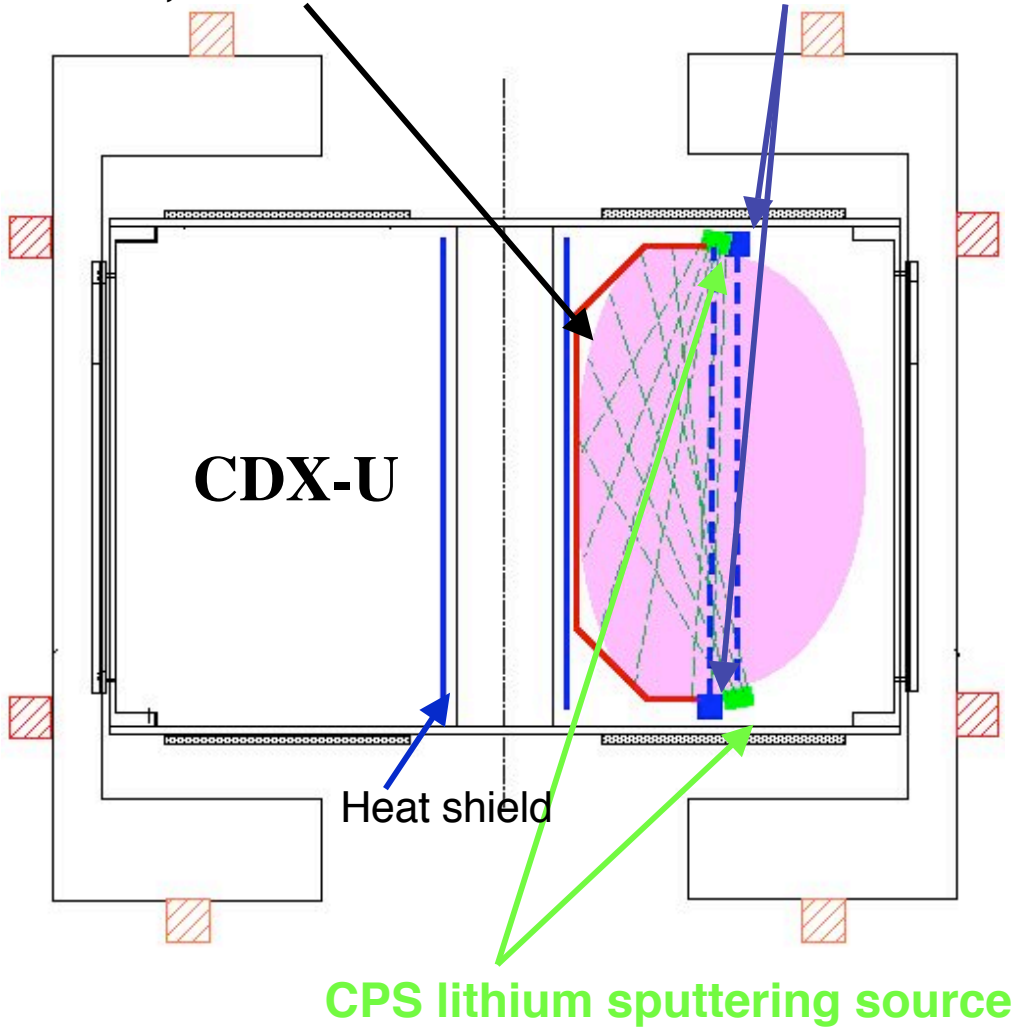
1) Characterize Low-Z Pellet Injection in NSTX

- Inject C,B, Li pellets (20-400 m/s)
- Probe NSTX edge transport barriers,flows, and rotation
- Measure
  - Pellet ablation along radial trajectory
  - Impurity transport from midplane to core & divertor

2) Particle Control Using Lithium Wall Coatings via Pellet Injection

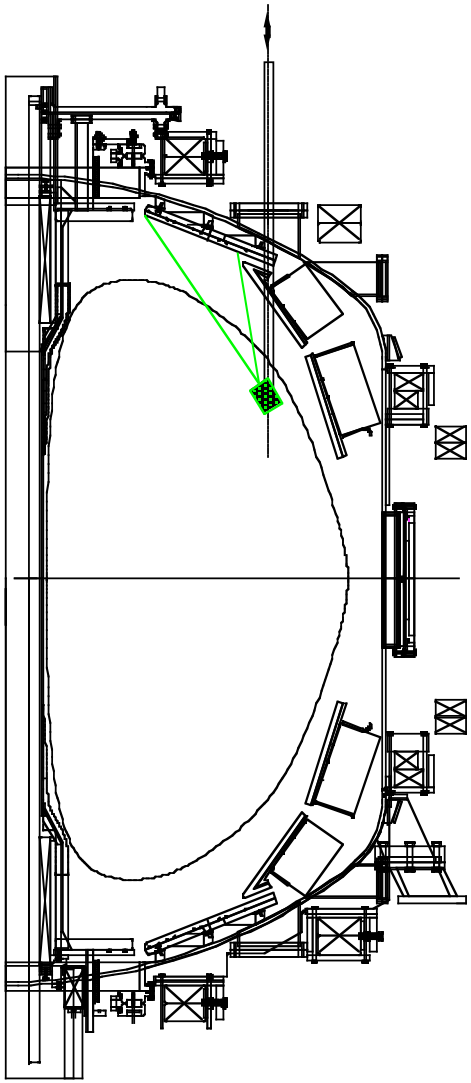
- Use results from the pellet characterization experiments to select the optimum discharge conditions and pellet deposition region
- Injection early in discharge of interest
- Injection near termination of preceding discharge
- *Measure:* ***recycling, fueling efficiency, confinement, profiles,transport, neutron and power yields***

Module A Test Limiter in CDX-U



- Single toroidal location
- Limiter will utilize 11 rectangular tiles
  - Curved on P-F side
  - Approx. 10 x 15 cm ea.
  - 1,650 cm^2 total area
  - Comparable to tray area
  - 60^o coverage of C-S
  - Heated
- Two e-beam sources.
  - Try electrostatic focussing; allow magnetic guide field (using PF coils).
  - One up, one down.
  - Fixed, above/below plasma LCFS.
- Two lithium sources.
  - One upward facing, one downward facing.
  - Russians interested in supplying sources (CPS)
  - Sources will be fixed during operation

NSTX Lithium Divertor Coatings



- Goal: Control divertor recycling using between-shots application of lithium coatings to the outer divertor tiles
  - Is lithium-on-graphite acceptable? Or is metallic lithium on an impenetrable substrate needed?
- Install an insertable e-beam (or resistively heated) deposition system (upper port as shown)
- Deposit few 1000Å of lithium. Withdraw deposition system.
  - Reminiscent of the insertable getters used in PLT, PBX
  - But time scale is different
    - Few 10's of seconds for 1000Å coating
    - Cycle time is dominated by insertion/removal of deposition source.
- Coat before *every shot*
  - 1000 shots ⇒ 0.1 mm accumulation
    - Accumulation may be limited by evaporation

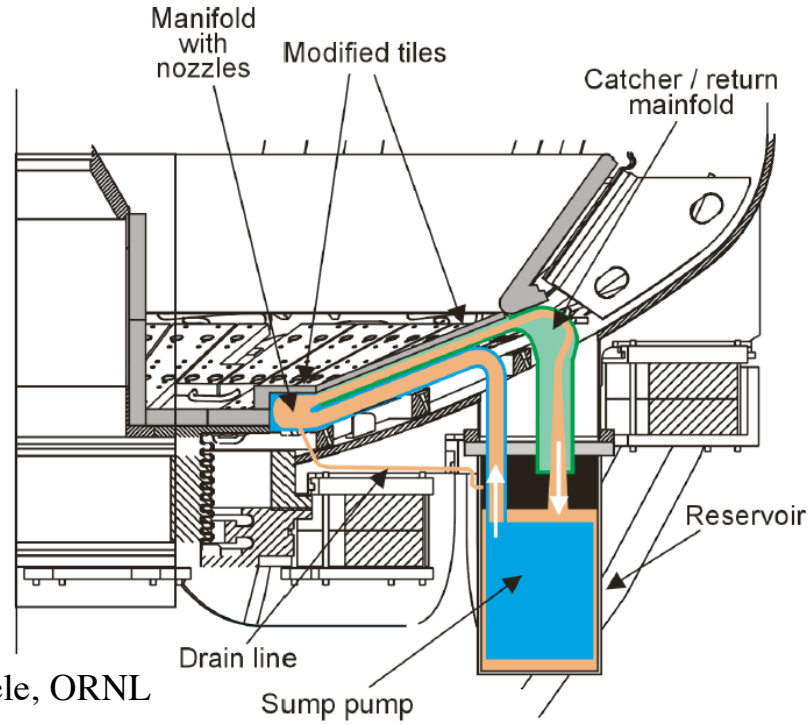
Particle Pumping by Lithium Coatings

- Estimated Capacity for Film on Vessel Walls:
  - –Area of passive plates is ~1.5 x 10^5 cm^2.
  - –Volume of 1000Å coating: 1.5 cm^3 (~ 6 x 10^{22} atoms)
  - – ~ 6 x 10^{20} particles in an NSTX discharge
  - –Wall has the capacity to pump the discharge for many particle confinement times

- Estimated Capacity for Film on Entire Divertor:
  - –Area ~ 3.6 x 10^4 cm^2
  - –1.5 x 10^{22} atoms
  - – Less capacity if only active area is considered
    - »May require strike-pt sweeping to pump the divertor.

Liquid Lithium Surface Module Will Address Important Reactor Issues

- Development by Virtual Laboratory for Technology
- A potential solution for both power and particle handling
  - -tantalizing possibilities for advanced regimes
  - -Liquid Li tray in CDX-U dramatically reduced recycling



C.Eberele, ORNL

- Modules ~ 1 m^2 close to plasma
- Flow liquid Li at ~7-12 m/s to avoid evaporation at full power
- The design will be based on edge and MHD modeling of data from CDX-U, NSTX, and the new Lithium Tokamak Experiment (LTX).
- Installation in FY'08

The Path to NSTX Lithium Operations

- **The NSTX Lithium Plan has been adopted to facilitate NTSX performance and mission**
  - **NSTX is not a technology development project**
    - ***Near term R&D support is requested to develop lithium evaporator technology for operation in FY05 and possible installation on NSTX and testing in FY04***
- **Each step of the NSTX Lithium Plan is required to pass a rigorous design, procedure, & safety review process**
  - ***R&D support is requested for this review process***

1) Requested Near Term R&D Support for NSTX Lithium Operation

• *RE Lithium Evaporation Technology*

- **Provide CDX-U as a test bed for NSTX Lithium development and issues**
- **Assist with the development of an evaporative coating system for CDX and NSTX tests**
- **Investigate composition of impurity layers on lithium formed in CDX and NSTX**
- **Model thermal response of lithium coating and substrates for NSTX conditions**
- **Model effects of sweeping divertor leg**

2) Requested Near Term R&D Support for NSTX Lithium Operation

- ***RE NSTX Design,Procedure, & Safety Review process***
- **Determine compatibility of evaporated lithium coatings with**
  - ***PFC substrate materials (ATJ graphite)***
  - ***Vacuum materials***
    - **alumina, BN, Macor, Vespel, Mylar, ceramic cement**
    - **fiberglass cable insulation**
    - **304-SS, Cu, Mo, W**
    - **present boronization coatings on vessel surfaces (BC_3)**
    - **viewports (glass, xtal quartz, fused silica, BK7, Be, sapphire, ZnSe)**
    - **special coatings (carbon paint optical dumps (lampblack))**
  - ***Processes***
    - **Boronization using Deuterated Trimethylboron [$B(CD_3)_3$] in HeGDC**
    - **HeGDC between discharges**
    - **350 C° bakeout of PFCs, 150C° bakeout of vessel wall**
    - **During bakeout D_2GDC followed by HeGDC**

Summary and Conclusions

- The NSTX lithium plan has been adopted to facilitate NTSX performance and mission.
- Lithium Pellet Injection experiments will characterize lithium coatings and pellet behavior in ST's (FY'04).
- Higher yield film deposition techniques will use a between-shot lithium evaporator to coat the passive plate and divertor tiles(FY'05).
- A Liquid Lithium Surface Module (LLSM) will address active pumping and assist with power handling (FY'08). The design will be based on edge and MHD modeling data from CDX-U, NSTX, and LTX.
- NSTX needs near term support to facilitate the development and deployment of the required technology, and assistance with the Design and Procedure Review process.